VISIT…

Source: DESIGN FOR MANUFACTURABILITY HANDBOOK

CHAPTER 3.7
COLD-HEADED PARTS

Charles Wick
Consultant

THE PROCESS

In cold heading or upsetting, force applied by one or more blows of a tool displaces metal in a portion or all of a slug, wire, or rod blank. This plastic flow produces a section or part of different contour, larger in cross section than the original material. Force is generally applied by a moving punch to form that portion of the blank protruding from a stationary die. As seen in Fig. 3.7.1, some parts are upset in the punch,

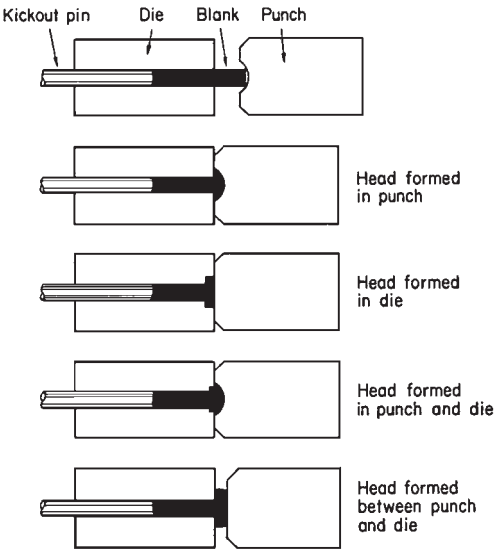

FIGURE 3.7.1 Upsetting can be done in the moving punch, in the stationary die, in both punch and die, or between the punch and the die. (*National Machinery Co.*)

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

some in the die, some in both punch and die, and others between the punch and the die.

Related Processes

Upsetting is often combined with forward or backward extrusion, particularly in cold-forming large-headed, small-shanked parts. Warm heading is applied for processing difficult-to-head metals such as medium-to high-carbon steels, austenitic stainless steels, and other materials that work-harden rapidly. In this compromise between cold and hot heading, the metal is preheated to between 150 and 540°C (300 and 1000°F) or more (depending on the particular metal, but below its recrystallization temperature) to increase its plasticity and reduce the force required for heading.

Rotary forging is a related process in which deformation is induced progressively rather than by a single direct squeeze. The workpiece is subjected to a combined rolling and squeezing action to produce progressive upsetting. This method is particularly suitable for thin, intricate flange sections.

Secondary Operations

Many secondary operations are performed on cold-upset parts, depending on the design and application of the part. These include grooving, shaving, pointing, flattening, bending, piercing, drilling, tapping, threading (often done with a thread-rolling machine made an integral part of the header), heat treating, and plating.

Cold-Heading Machines

Most cold-heading machines used in high production are fed coil stock. A machine may include a straightener, draw die, feed rolls, and shear. Sheared slugs are automatically transferred to a stationary die, and the projecting end of each slug is struck axially by the upsetting tool (punch). In some cases, as in nail making, the stock can be upset first and then sheared to length. Multistation and progressive headers, as well as bolt-making machines, are equipped with automatic-transfer mechanisms to move parts to successive stations and may have trimming, pointing, and thread-rolling stations.

Headers and forming machines are available in a wide variety of sizes and types. They are frequently rated by maximum-diameter-cutoff capacity and feed lengths (generally up to 14 times rated diameter, but this capacity can vary).

TYPICAL CHARACTERISTICS OF COLD-UPSET PARTS

Cold upsetting and heading are best suited to the high-volume production of relatively

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

small parts. Producing heads on a wide variety of fasteners is still the greatest single use of the process. However, when combined with other metal-forming operations such as extruding, piercing, trimming, and threading, the process is being increasingly applied to the production of many different parts. Raw materials range up to 50 mm (2 in) or more in diameter. The size of upset parts varies from balls $\frac{1}{2}$ mm (0.020 in) in diameter to large shafts, stem pinions, and other parts weighing 3.2 kg (7 lb) or more. The longest pieces headed on commonly used equipment are about 230 mm (9 in) long, but special machines will handle longer parts. Materials used range from aluminum alloys to medium-carbon steels. Stainless steels as well as copper and nickel alloys are also cold-formed.

Cold-headed parts have improved physical properties, with metal-grain flow lines following the contours of the parts. They have smooth surfaces and an absence of stress-inducing tool marks. On the other hand, there are limitations on the intricacy of the parts that can be produced. Undercuts, reentrant shapes, and thin walls normally are not feasible. Shank ends of parts are usually irregular, and secondary operations are necessary if the ends must be fully square. Screw machines are often preferred for shorter production runs and for parts requiring intricate forms, sharp angles, and closer tolerances.

Typical applications of cold-upset parts include, in addition to conventional fasteners, the following: valves, knobs, shelving spacers, electrical contacts, cams, terminal posts, rollers, shafts, balls, bearing races, electrical terminals, transistor bases, wrist pins, cable connections, spark-plug bodies, ball-joint housings or sockets, spindles and shafts, gear blanks, pistons, hose fittings, switch housings, pipe plugs and fittings, wheel hubs, and stub axles. Figures 3.7.2 and 3.7.3 illustrate typical examples.

ECONOMIC PRODUCTION QUANTITIES

Cold-upsetting or -heading processes are most suitable for producing large quantities of relatively small metal parts. Long production runs are desirable because the relatively high cost of tools and the substantial setup time can be distributed over a large number of workpieces, thus reducing the unit cost. Also, initial investment in capital equipment (large progressive headers and part formers) is expensive, but write-offs can be rapid with sufficient production requirements.

Minimum-quantity levels for economic production generally range from 25,000 to 50,000 parts, but quantities as low as 1000 have been produced. The exact minimum run for economic production depends on many factors, including the size and shape of the workpiece, the material from which it is made, tooling cost, setup time, and the costs of competitive processes.

Cost of the raw material can be a significant factor affecting the competitiveness of the process. As the material cost increases, the quantity of parts required to justify the process decreases because of material savings (little or no waste). However, parts made of high-carbon and alloy steels as well as other less ductile materials are generally uneconomical to produce in this way because of the higher pressures required (necessitating more costly equipment) and the possible need for several operations with intermediate annealing treatments.

Many parts previously made on screw and automatic bar machines are now being produced on headers and formers. One rule of thumb is that cold heading will be more

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

FIGURE 3.7.2 One die and two punches form these double-blow cold-headed parts. (*National Machinery Co.*)

FIGURE 3.7.3 Combination cold-heading and thread-rolling machines form these completed fasteners. (*National Machinery Co.*)

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

economical than machining if shank length is more than 3 times the shank diameter of the part and production requirements are sufficiently high.

GENERAL DESIGN CONSIDERATIONS

All parts to be upset should be designed for the smallest stock diameter possible, minimum amount of upset, smallest-diameter head (or other upset portion), and fewest strokes necessary to satisfy requirements. Thin, large-diameter heads (in comparison with the original wire diameter) are more difficult to upset than thicker ones. Symmetrical parts are the easiest to cold-form, but unsymmetrical parts can be produced. No draft allowance is required, but parts must be designed so that they can be removed from the tooling.

Designers should try to visualize optimal metal flow in the design of parts to be upset. For example, generous fillets and rounded corners facilitate metal flow.

Close cooperation between designer and manufacturing engineer often can improve a part and reduce its cost. Parts originally designed to be made by some other process may require modifications to permit upsetting at low cost. Sometimes two or more functional components can be combined into a single upset part, thereby eliminating assembly costs.

SUITABLE MATERIALS

Any material that is malleable when cold can be cold-formed. Materials having the lowest yield strength and the greatest range between yield and ultimate strengths are the most malleable. Since strain or work hardening during cold working decreases formability, the rate of strain hardening of the material is an important consideration. Hardness of the material is also critical, since too hard a material is impracticable to cold-work.

Prior operations, sometimes required to prepare material for upsetting, can include heat treating, drawing, descaling, and lubricating. The upsetting properties of most steels are improved by annealing or spheroidizing.

Whenever possible, the designer should avoid specifying exact material analyses, since this limits the upsetter's flexibility and may increase production costs. Several different analyses of a basic material often can satisfy service requirements, but they may vary in upsettability, availability, and cost.

Steels

Low-carbon steels such as 1006 (G10060), 1008 (G10080), 1010 (G10100), 1012 (G10120), 1015 (G10150), and 1018 (G10180) are the easiest to upset. Such steels have a carbon content too low to permit a marked response to heat treatment, but they have a minimum tensile strength of 380 MPa (55,000 lbf/in^2), and physical properties can be substantially improved by cold working. If wear-resistant surfaces are required, they can be case-hardened. When subsequent through-hardening is required, medium low-carbon steels such as 1019 (G10190), 1022 (G10220), and 1025 (G10250) are

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

used.

Medium high-carbon steels such as 1038 (G10380) are also fairly easy to cold-work but more difficult than low-carbon steels, and their headability decreases as their carbon content increases. Such steels are used for parts requiring a minimum tensile strength of 830 MPa (120,000 lbf/in^2).

High-carbon steels containing up to about 0.62 percent carbon are cold-upset, but they have limited workability, and maximum carbon contents of about 0.50 percent are generally recommended. Rapid work hardening of higher-carbon steels restricts the amount of cold working possible without annealing.

The chemical composition of carbon steels also can affect their headability. A silicon content of more than 0.35 percent can increase the rate of work hardening and resistance to plastic flow. A manganese content above 1.00 percent also may increase pressure requirements. Sulfur content should be limited to about 0.05 percent. Resulfurized steels generally are not recommended but may be necessary when subsequent machining is required. Phosphorus contents greater than 0.04 percent also can cause higher pressure requirements.

Alloy steels are more difficult to cold upset, but parts are produced from such materials. Alloy steels such as 4037-H (H40370), 4118 (G41180), 8620 (G86200), and 8640 (G86400) are suitable for cold upsetting and have strengths suitable for many fasteners and other cold-headed parts. The nickel content of alloy steels should be limited to about 1.00 percent, chromium to about 0.90 percent, and molybdenum to about 0.40 percent for best results. Limitations on manganese content depend on the carbon content of the alloy steel, from as much as 1.35 percent manganese in steels containing up to about 0.12 percent carbon to 0.90 percent manganese in steels containing up to 0.30 percent carbon. In some cases, small amounts of boron in the steels can achieve hardness requirements while allowing the use of more easily formed lower-carbon materials.

Rimmed steels are ideal for heading operations when large surface expansions are required, but such steels generally are not satisfactory for cold extrusion. As a result, killed steels are usually preferred for cold-forming operations combining upsetting and extruding. Vacuum degassing of steel at the mills is recommended by some upsetters. Heat treatment, preferably spheroidize-annealing, to establish the microstructure of the material is an important consideration. The hardness of the steel that is best suited for upsetting generally varies from about R_b 72 for low-carbon steels to about R_b 85 for higher-carbon and alloy steels.

Cold heading or upsetting is carried out with either hot-rolled or cold-drawn steel. The surface quality of the raw material is also important. The material should be free of surface imperfections such as scratches, seams, folds, and blisters, which can cause cracking during deformation and mar the appearance of the finished part. Cold-heading-quality steel, which has sufficient surface stock removed to eliminate deep seams, is available from mills.

Internal material defects such as porosity and nonmetallic inclusions also can cause failures in upsetting, but they are even more critical in extruding. When parts are to be cold-formed by upsetting and extruding, cold-extrusion-quality steels (having better surface quality and uniform internal structure) are often specified.

Stainless Steels

High initial strength and rapid work-hardening characteristics make stainless steels

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

more difficult to cold-upset, but some grades work-harden less rapidly and are more formable than others. Stainless steels most widely cold-headed include the austenitic types 305 (S30500) and 316 (S31600) and the ferritic and martensitic types 410 (S41000) and 430 (S43000). Type 410 is one of the most widely used hardenable corrosion-resistant steels for upsetting, but type 430 (a ductile, nonhardenable type) is more corrosion resistant. Type 384 (S38400), which was developed for cold heading, provides a good combination of headability and corrosion resistance.

Stainless steels that have higher work-hardening rates and less headability include types 302 (S30200), 304 (S30400), 309 (S30900), 310 (S31000), 316 (S31600), 431 (S43100), and 440C (S44004). Most of these require less severe cold heading, and some cannot be considered for producing recessed-head-type fasteners.

Nickel Alloys

Cold-heading properties of nickel-alloy materials range from good to poor. Monel metal has fairly good cold workability, and Nichrome is also readily cold-worked. Inconel also is cold-headed, but this is more difficult.

Aluminum Alloys

Aluminum alloys are among the most easily headed materials. The most widely used alloy is 2024 (A92024), which is generally upset in the H13 temper and then heat-treated to the T4 condition. The most easily headed aluminum alloys are 1100-0 (A9110-0), 1100-H14 (A91100-H14), 6053-H13 (A96053-H13), 3003-0 (A93003-0), 3003-H14 (A93003-H14), 6061-0 (A96061-0), and 6061-H13 (A96061-H13). The next most easily formable are 2117-0 (A92117-0), 2117-H13 (A92117-H13), 2117-H15 (A92117-H15), 2017-O (A92017-0), 2017-H13 (A92017-H13), 2024-0 (A92024-0), 2024-H13 (A92024-H13), 5005-0 (A95005-0), 5005-H32 (A95005-H32), 5052-H32 (A95052-H32), 5056-0 (A95056-0), and 5056-H32 (A95056-H32). Somewhat less headable are 7575-0 (A97075-0), 7075-H13 (A97075-H13), and 7178-H13 (A97178-H13). Aluminum alloy 6061-T913 (A96061-T913), used only for nail wire, is more difficult to head.

Copper and Copper Alloys

Copper and alloys such as brass and bronze also possess excellent heading properties, and their hardness and strength can be improved considerably by cold working. Brass containing 65 to 70 percent copper and 30 to 35 percent zinc is widely used and easily formed into intricate shapes. Commercial bronze (90 percent copper, 10 percent zinc) has better cold-working properties than the brass just described. The electrolytic-tough-pitch (ETP) type is the copper most widely cold-headed, but oxygen-free and tellurium coppers can be formed just as easily. Care is required in upsetting leaded copper alloys because of the possible danger of splitting the material.

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

Other Materials

Titanium, beryllium, and refractory metals are less formable at room temperatures, and they are likely to crack when cold-headed. As a result, they are often processed warm.

DETAILED DESIGN RECOMMENDATIONS

Maximum Upset Diameters

When low-carbon steel is upset, there are limitations on the ability of the material to deform without cracking or splitting. Figure 3.7.4 shows generally accepted maximum

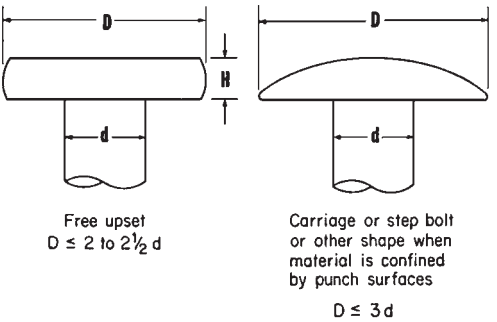

FIGURE 3.7.4 Generally accepted maximum upsetting diameters.

upset diameter limits. Free upsets between die and punch do not contain the metal at the sides of the upset, and under these conditions, the maximum upset diameter is about $2\frac{1}{2}$ times the blank diameter. If the metal is contained in or controlled by punch surfaces, the maximum upset diameter is about 3 times the blank diameter. The exact maximum diameter depends on the material quality, and there are examples of upsetting carried out at 4 times the blank diameter.

Lengths

The length of a headed part is considered to be the distance from the extreme end of a given piece to the nearest point at which the diameter of the upset portion is at maximum. As a general rule, the length for cold heading should be between one diameter of the stock and 150 mm (6 in) for the most economical operation. If the length is shorter than one diameter, handling becomes difficult and usually requires special tooling. For parts longer than 225 mm (9 in), special equipment such as rod headers may be required.

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

Amount of Upset

The maximum length that can be upset without unwanted bending is expressed in multiples of the blank diameter. A general rule is that up to $2\frac{1}{4}$ to $2\frac{1}{2}$ diameters in length can be upset in one blow. If this volume is not enough to form the required upset, two blows must be used. Up to about $4\frac{1}{2}$ diameters generally can be upset in two blows and 6 to 8 diameters with a triple blow. For economy, parts should be designed to require the smallest number of blows.

Part Symmetry

Parts symmetrical about their axes are the easiest to form because they permit even metal flow and balanced forces against the tool. Although asymmetrical parts can be produced, they may exhibit interrupted grain flow and entail more complex tooling and shorter tool life.

Head Shape

Unless flats are required on heads for wrenches or some other contour is necessary, circular heads should be specified for maximum economy. Square, rectangular, hexagonal, and other shapes of heads are commonly produced, but if sharp edges are required, trimming is generally necessary, thus adding to the cost. Tighter tolerances can be maintained when an indentation on the head of a part is placed as closely as possible to the body or shank axis.

Recesses and Slots

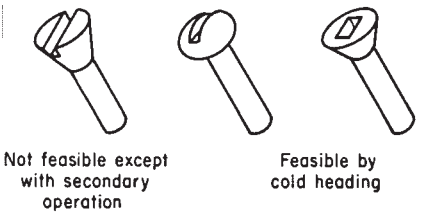

FIGURE 3.7.5 Cold-formed screwdriver slots.

Hollow upsets should be avoided when possible because they require more die maintenance and there is a possibility of cracks forming around the edges of the recesses. However, many fasteners with hexagonal-socket heads and other special recesses are being produced successfully on cold headers. Recesses in such heads should not extend into the bodies of the formed parts.

Screwdriver slots can be cold-formed in the heads. In flat-headed parts, the slot must have a curved (instead of a flat) bottom to eliminate contact between the slotting punch and the dies. In round-headed parts, the slots can be straight. (See Fig. 3.7.5.)

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

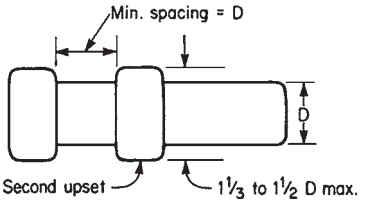

FIGURE 3.7.6 Design rules for second upsets.

Collars or Double Heads

When a second upset is produced some distance from the end of the part, it must be small enough to drop from the dies as they are released and cannot generally be more than one-third to one-half larger than the diameter of the wire being used. Upset sections also should be at least one wire diameter apart. (See Fig. 3.7.6.) Double heads or collars that exceed these limits usually must be made by a secondary upsetting or machining operation.

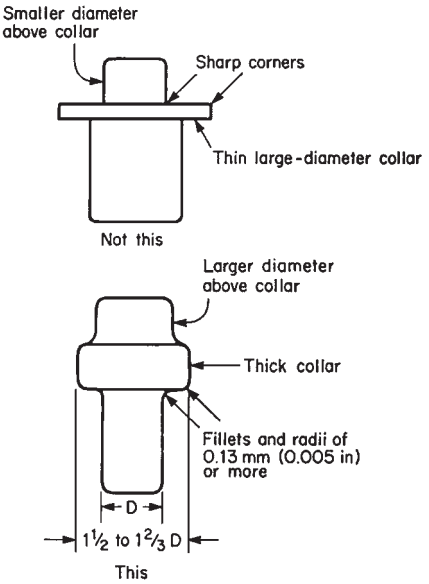

FIGURE 3.7.7 Collars are easier and more economical to form if the diameter above the collar exceeds that below. Thin, large-diameter collars are harder to produce than thick ones. Collar diameters should be in the range of $1\frac{1}{2}$ to $1\frac{2}{3}$ times the wire diameter for maximum economy in upsetting. Normal flow of material produces slightly rounded edges on collars. Radii and/or fillets make cold-upset parts more economical and easier to produce.

Round, square, and hexagonal collars are most common. Such collars are easier and more economical to form if the diameter above the collar exceeds the diameter below the collar. Thin, large-diameter collars, as in the case of heads, are harder to produce than thick ones. For maximum economy, they should be in the range of $1\frac{1}{2}$ to $1\frac{2}{3}$ times the wire diameter. (See Fig. 3.7.7.)

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

Collars often require sharp corners, but economical cold heading requires forming with slightly rounded edges. A typical collar rounding with normal flow of material during heading is also shown in Fig. 3.7.7. If straight sides and sharp corners are required, a trimming or secondary shaving operation is necessary.

Corners

As in all cases of plastic flow, sharp corners should be avoided because they interfere with smooth metal flow, make it difficult to fill, reduce tooling strength, and can cause stress concentrations. Parts with radii and fillets are more economical and easier to produce. A minimum radius of about 0.13 mm (0.005 in) and even more for stainless steels and nickel alloys, depending on part size and location of the radii, is recommended. Axial undercuts, such as the ones shown on the part in Fig. 3.7.8, can be formed in cold heading, and they are almost always less expensive than producing square corners.

Shanks

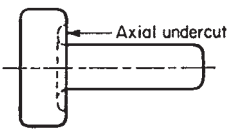

FIGURE 3.7.8 Undercut beneath the head of this stainless-steel plunger is formed during upsetting and eliminates the need for producing square corners.

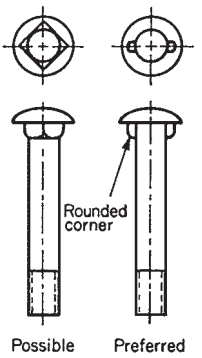

FIGURE 3.7.9 Tooling is simplified if two or four lugs are used instead of a square shank.

When a shank must have some portion that is noncircular in section, the length of that portion should be kept to a minimum. Also, when a shank requires multidiameters, a generous radius or taper should be provided between diameters.

Locking devices to prevent fasteners from rotating (such as square shanks below the heads) can be cold-formed, but tooling is simplified and costs reduced if two or four lugs are specified instead of a square shank (Fig. 3.7.9).

Serrations, Ribs, and Knurls

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

Only straight knurls can be produced in heading, and they normally require a draft or taper of about 2° to facilitate removing the part from the punch and die. Sharp diamond-pattern knurls or straight knurls without taper must be rolled after upsetting and are therefore less economical.

Headed knurls are not usually as sharply defined as those produced by trimming or rolling and are therefore not recommended for press fits, close tolerances, or cases in which maximum holding power is recommended.

Lugs, Fins, Projections, and Dimples

Lugs form best on cold-headed parts when they are designed with a radius on their bottom and do not extend to the edge of a head, as shown in Fig. 3.7.9. When lugs are extended to the edge of a head, they will not usually fill out sharply, and a somewhat irregular configuration can be expected. If a projection or dimple (as for welding) is needed near the edge of a head and it is not joined to the body or shank of the part, it should be placed at least one projection diameter from the body and at least 0.8 mm ($\frac{1}{32}$ in) from the perimeter of the head.

Points or Chamfers

Forming of points or chamfers on cold-headed parts is generally limited to parts having a length 10 to 12 times the smallest diameter at the pointed end when an unsupported knockout pin is used and up to 20 diameters with a supported pin (Fig. 3.7.10). For parts beyond these limitations, the point usually must be machined in a subsequent operation.

Embossing

Forming of numbers, letters, or other identification marks on parts in a header may add slightly to the cost, but it is generally cheaper than processing the parts through a secondary operation. Depressed characters in the part are usually cleaner and more legible. However, tooling tends to wash off in service, and it therefore may be expen-

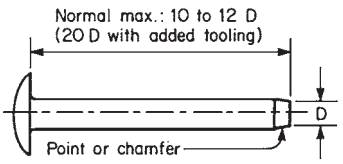

FIGURE 3.7.10 Length of parts having formed points or chamfers is generally limited to 10 to 12*D* with unsupported knockout pins and up to 20*D* with supported pins.

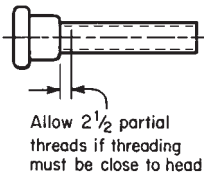

FIGURE 3.7.11 Recommended maximum distance from the underside of the head or shoulder to the first complete thread is $2\frac{1}{2}$ threads for sizes up to 1 in in diameter.

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

sive in the long run. Depression in the punch, producing raised lettering in the part, allow longer tool life, but character legibility is not as good.

Threading

On parts for which thread length must be as close to the head as practicable, maximum allowable distance from the underside of the head to the first complete thread should be specified. As shown in Fig. 3.7.11, this should be $2\frac{1}{2}$ threads for sizes up to 25 mm (1 in) in diameter and $3\frac{1}{2}$ threads for larger sizes.

Combining Parts

Designers should give major consideration to the possibilities of combining two or more components into a single cold-formed part. Advantages of such designs include reduced costs and increased part strength. Examples include fasteners combined with spacers, washers, or special heads

DIMENSIONAL FACTORS AND TOLERANCES

Tolerances that can be maintained in cold upsetting vary with the style (shape and volume) of the upset, length-to-diameter ratios, material being formed, part size, quality of the machine and tooling, and other factors. Also, after prolonged use, tooling wears

TABLE 3.7.1 Tolerance Ranges for Upset-Head Heights and Diameters

	Tolerance ranges*	
Nominal shank diameter, in	For upset height, in	For upset diameter, in
1/16	0.008	0.014
1/8	0.010	0.018
3/16	0.012	0.021
1/4	0.014	0.025
5/16	0.015	0.029
3/8	0.017	0.032
7/16	0.019	0.036
1/2	0.021	0.040
5/8	0.02 5	0.048
3/4	0.028	0.055
7/8	0.032	0.062
1	0.036	0.070

*Tolerance range generally applied bilaterally. For example, a range of 0.014 would be ± 0.007 in.

Source: Industrial Fasteners Institute.

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

TABLE 3.7.2 Tolerance Range on Shoulder Diameters (Round, Square, and Hexagonal), in

Body size	Economical	Normal	Expensive
0.029–0.099	±0.0025	±0.0015	
0.100–0.179	±0.003	±0.0015	±0.001
0.180–0.312	±0.003	±0.002	±0.0015
0.313–0.500	±0.0035	±0.0025	±0.0015
Tolerance range on shoulder lengths, in			
0.0029–0.500	±0.0075	±0.0055	±0.0025

Source: Elco Industries, Inc.

TABLE 3.7.3 Tolerance Range on Hexagonal-, Round-, and Square-Collar Diameters, in

Body size	Economical	Normal	Expensive
0.070–0.125	±0.004	±0.0025	±0.0015
0.126–0.250	±0.005	±0.003	±0.002
0.251–0.375	±0.006	±0.004	±0.0025
0.376–0.625	±0.007	±0.005	±0.003
0.626–$1\frac{1}{8}$	±0.008	±0.006	±0.0035

Source: Elco Industries, Inc.

TABLE 3.7.4 Tolerance Range for Unthreaded-Body Diameter (below Shoulder or above and below Collars), in

Body size	Economical	Normal	Expensive
0.029–0.099	±0.002	±0.001	±0.0005
0.100–0.179	±0.002	±0.001	±0.00075
0.180–0.312	±0.002	±0.0015	±0.001
0.313–0.500	±0.0025	±0.002	±0.0015
0.501–0.562	±0.0025	±0.002	±0.0015

Note: The shape and volume of the material in the head determine the allowable tolerances to be held on an unthreaded-body section.

Source: Elco Industries, Inc.

and parts lose size. Tolerances are primarily a function of tool-manufacturing practices and wear, and smaller parts generally can be held to closer tolerances.

As with any manufacturing process, part costs increase when closer tolerances are specified. Care should be exercised not to specify tolerances closer than those actually required for the specific application of the part. Tolerances should be as liberal as possible for increased economy, longer production runs (due to prolonged tool life), and

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

reduced scrap.

Diameters

TABLE 3.7.5 Tolerance Range for Collar Thickness, in

Body size	Economical	Normal	Expensive
0.030–0.062	±0.004	±0.0025	±0.0015
0.063–0.125	±0.005	±0.003	±0.002
0.126–0.250	±0.006	±0.0035	±0.0025
0.251–0.312	±0.007	±0.004	±0.003
0.313–0.500	±0.008	±0.0045	±0.0035

Source: Elco Industries, Inc.

TABLE 3.7.6 Length Tolerances for Headed Parts

For lengths, in	Tolerance range, in
For diameters up to and including ¾ in	
Up to 1	1/32
Over 1 to 2	1/16
Over 2 to 6	3/32
Over 6	3/16
For diameters over 3/4 in	
Up to 1	1/16
Over 1 to 2	1/8
Over 2	3/16

Source: Industrial Fasteners Institute.

Diameter tolerances can easily be maintained within those specified for standard fasteners. Tolerance ranges for the diameters of upset heads are given in Table 3.7.1, shoulders in Table 3.7.2, collars in Table 3.7.3, and bodies or shanks in Table 3.7.4. These tolerances are not necessarily limitations but can be used as a guide. The tolerance ranges listed as economical are the most easily held. Although those listed as normal are more costly, they do not generally require secondary operations, but special tooling may be needed. Tolerance ranges listed as expensive may require secondary operations.

Lengths

Tolerance ranges for the heights or lengths of upset heads are given in Table 3.7.1,

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.

shoulder lengths in Table 3.7.2, collar thickness in Table 3.7.5, and overall lengths in Table 3.7.6.

Other Dimensions

As wide a tolerance as possible should be allowed on lugs, fins, tapers and projections because metal-flow behavior is sometimes unpredictable in forming these shapes. Radii generally can be formed to tolerances of ±0.13 mm (0.005 in).

Geometry

Concentricity variations of 0.025 to 0.08 mm (0.001 to 0.003 in) TIR are not uncommon in blank sizes up to 6 mm (¼ in) in diameter if the difference between the two referenced diameters is not too great. Greater concentricity tolerance is generally needed for larger-size parts and larger differences in diameters. If closer tolerances are needed, secondary operations such as machining, shaving, or grinding are generally required.

Straightness of cold-upset parts can generally be held to about 0.4 percent of length.

Surface Finishes

A finish of 0.4 to 0.8 μm (16 to 32 μin) usually can be obtained economically. Upsetting of heads, however, sometimes can decrease the quality of surface finish unless high pressures are exerted on the sidewalls of the containing die. High-quality finishes generally also require the use of high-quality clean wire.

Surface finish also can vary among different parts or different areas of the same part, depending on the surface of the wire or bar being headed, the amount of cold working performed in various areas, the lubricant used, and the condition of the tools. The best finish on any part is usually achieved when direct contact has been made with the tools.

Downloaded from Digital Engineering Library @ McGraw-Hill (www.digitalengineeringlibrary.com)
Copyright © 2004 The McGraw-Hill Companies. All rights reserved.
Any use is subject to the Terms of Use as given at the website.